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THE APPLICATION OF ENTROPY-ROV METHODS TO FORMULATE GLOBAL PERFORMANCE FOR SELECTING THE AUTOMOTIVE SUPPLIERS IN MOROCCO.

MOUNA EL MKHALET[1], SOULHI AZIZ[2], RABIAE SAIDI[3]

[1]PhD student at Laboratory LASTIMI, CEDOC EMI, Rabat, Morocco
[2]Professor at Ecole Nationale Supérieure des Mines de Rabat, Agdal Rabat, Morocco
[2]ORCID: 0000-0003-1904-513X and the Scopus Author ID: 42162322200
[3]PhD student at Laboratory LASTIMI, CEDOC EMI, Rabat, Morocco
E-mail: [1]mouna.doctorat.2018@gmail.com,[2]soulhi@enim.ac.ma, [3]rabiae.saidi@laposte.net

ABSTRACT

In Morocco, the automotive sector is constantly improving because it occupies an important place in the Moroccan economy; this is why our research will be in this context in order to bring added value in term scientist. The study we are conducting proposes, firstly, the selection of best AKPI: Appropriate Key Performance Indicators in an objective and utilitarian way, by the application of the combined method ENTROPY-ROV (Range of Value) in the Moroccan automotive sector, and then realize the formula of Global Performance. Secondly, this one will be used to select the best supplier in the Moroccan industrial automotive sector. Furthermore, the results obtained by the application of Entropy-ROV shows that the highest weight among the AKPIs are Machine Availability and the Number of Occupational Injuries, which respectively correspond to the key factors of success: Efficiency of Production Systems and Health and Safety: which requires improvement on the part of Moroccan companies in automotive sector. We also find that the calculation of Global Performance for suppliers shows, that the best supplier is the supplier2 which ranks first among the others. In addition when we compare the results obtained concerning the priority of the AKPIs and the choice of suppliers by the Entropy-ROV method in our research, to that of Chahid et al [28], who used the AHP method, we note that they are not the same. Finally, our contribution is to use for the first time, a scientific, quantitative and mathematical multi-criteria evaluation method called ENTROPY-ROV, which is a combined method, in the automotive industry in Morocco in order to select the best key success factors and to evaluate the suppliers in an objective and utilitarian way.

Keywords: *Entropy, ROV, Supplier selection, Appropriate Key Performance indicator (AKPI), Moroccan automotive industry*

1. INTRODUCTION

The automotive industry creates benefits and makes common advantages while relying on the mobilization of those who work there; it is therefore considered the company that creates more innovation and dynamism in upstream logistics [50].

In Morocco, the automotive sector is assumed to play an important role in economic development, this is due to the essential part of the business in the Moroccan economy (6% of GDP, 14% of exports), this is why Morocco aims to further develop and invest in this sector [51]. The automobile industries have a great impact in the development of the industrial sector in general in Morocco, and lower the unemployment rate by creating new jobs [52].

In relation to world production, Morocco is the second-largest car producer in Africa, after South Africa, with a 26% share of African production (636,519 vehicles), which represents only 0.73% of global car production in 2013 [52].

This table below shows the production of vehicles between 2003 and 2013, from the three African countries: South of Africa, Morocco and Egypt [52].

Tableau 1: the production of vehicles between 2003 and 2013, from the three African countries[52]

Country	2003	2013
South Africa	89%	69%

Morocco	5%	26%
Egypt	5%	4%

The concentration of the automotive industries, are in three zones of Morocco: Tangier (43 per cent), Casablanca (39 per cent) and Kenitra (7 per cent) [52] [64].

The figure below shows the location of the three Moroccan cities; where the automotive industries are largely concentrated.
These cities are located in northwestern Morocco.

Figure 1: locations of Tangier, Casablanca and Kenitra[65]

Regarding the exports of the Moroccan automobile sector, in recent years they have recorded a remarkable performance, rising from 12.7 billion dirhams in 2007 to more than 40 billion dirhams in 2014, an average annual growth rate of 21 percent. % as shown in the figure:

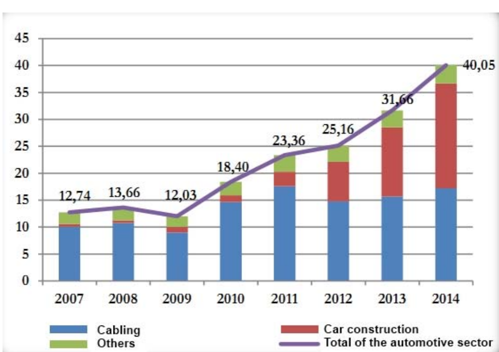

Figure 2: Evolution of automotive exports between 2007-2013 [52]

There was also a significant increase in skilled employment, which grew at a rate of nearly 16% per year between 2008 and 2012, from 38,795 jobs to 70,000 jobs: An additional creation of more than 31,000 jobs, as shown in Figure below:

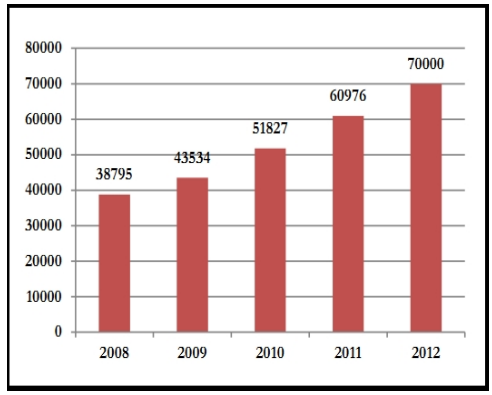

Figure 3: Evolution of employment in the automotive sector between 2008-2012[66] [52]

On the other hand, Braglia and Petroni [53] announce that supplier selection is a very important phase for any industry in its buying process. Sharma [54] stated that the selection of suppliers and their assessment is currently considered very important and relevant in any automotive company and industry.

Given the importance of selecting the best Key factor success and choosing the best supplier in the automotive sector in Morocco, we will see, through this study that we will conduct, in this paper, how we can select the Key factor success in an objective and utilitarian way through the use of Multi criteria decision making (MCDM) and how we can select the best supplier.

In terms of knowledge, we contribute to the Moroccan automotive industry sector by proposing a new quantitative and mathematical multi-criteria evaluation method called Entropy-ROV for the choice of key success factors and evaluation of suppliers. This creates a certain added value in the Moroccan automotive industry because it is a scientific evaluation method and generally Moroccans do not use scientific methods for evaluating suppliers.

The Moroccan industrial automobile sector fail to use a scientific approach because it requires scientific expertise, and I as a research scientist I could apply this method Entropy-ROV in the Moroccan automotive industry, which requires to follow the steps and to apply the equations carefully.

In the current literature, the entropy method has been used alone, and the ROV method has been used alone to solve some multi-criteria problems, it is in our research that this is the first time, that there is a combination of both Entropy

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and ROV methods in the Moroccan automotive sector to solve the problem of supplier evaluation and the selection of key success factors in a utilitarian and objective way.

2. METHODOLOGY

The following methodology was carried out to achieve the objective of this research: firstly, in the results section, we present the different methods used to select the best supplier in the automotive sector. Secondly, the entropy method is presented, and we give examples of the studies that used it. Then, the entropy's steps for calculate weight are presented with equations. In addition, the ROV: ranking of values method is presented and we give examples of the studies that used it. Then ROV's steps for calculate weight are presented with equations. Furthermore, we explain our contribution in this paper of research in the automotive sector in Morocco. Then, in the case study, the procedure applied in our research is applied in Figure 4:

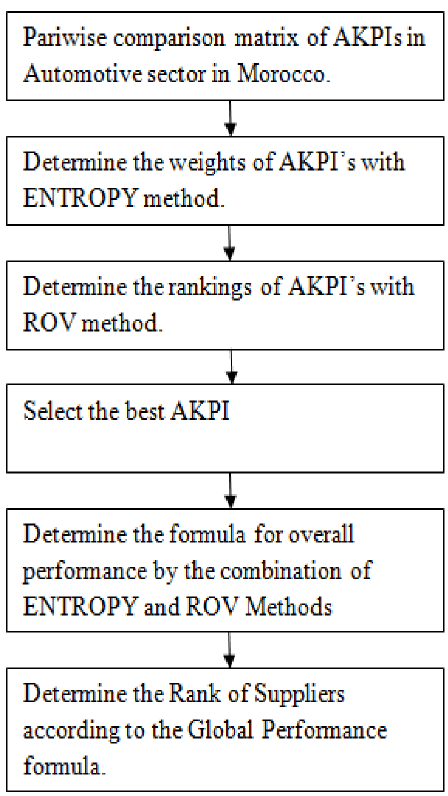

Figure 4: the procedure applied in our research

The weight of All Appropriate Key performance Indicators (AKPIs) for all automotive sectors in Morocco will be calculated by entropy method and then the ranking of the weight of AKPI's by ROV method is done. Then the graph of the AKPI's weight rankings obtained by the combination of the two methods mentioned, is clearly explained and analyzed. Then the formula of (GP) overall performance is expressed by the weights of combined Entropy-ROV method of the AKPI. Furthermore, we will apply this formula to choose the best supplier in the automotive sector in Morocco.

Finally, in the section: Discussion, through this paper, we will show the effectiveness of the method for the case studied.

3. RESULTS

3.1 The Methods Used For Selection Of Suppliers In Automotive Sector

In the company of automobile, in order to choose the best supplier, an integrated Balanced Scorecard–Fuzzy Analytic Hierarchical Process (BSC–FAHP) model was utilized by By Galankashi et al. [32]. To facilitate the selection of the best supplier in the industrial automotive sector, Beşkese and Şakra [33] conducted a research based on a hierarchical model applied to a multinational automobile company in Turkey, using fuzzy analytic hierarchy process (FAHP). Aksoy and Ozturk [34] used the Artificial neural networks (ANN), to apply them to data from an automotive company, in order to evaluate and select the best supplier. To solve the problem of selecting the best supplier, in an automotive company, Golmohammadi [35] designed a neural network model to evaluate the performance of suppliers and then the model was reevaluated to give them their score, and classify them. Percin [36] utilized an AHP-PGP: (Analytic hierarchy process and Multi-objective pre-emptive goal programming) approach for selecting the best supplier in automotive company in Turkey. Kull and Talluri [37] proposed a combination of AHP: Analytical hierarchy processes and PG: Goal programming to solve the problem of selecting the best supplier in the presence of risk in automotive company. Shahanaghi and Yazdian [38] applied the fuzzy TOPSIS method to select the best supplier in an automotive company. In an automotive production factory, the fuzzy TOPSIS and GP (goal programming) methods was used by Jolai et al. [39] in order to select the best supplier. Junior et al. [40] conducted a research based on the use of fuzzy TOPSIS and fuzzy AHP methods to facilitate the process of selecting the best supplier in automotive company. Fuzzy AHP, Fuzzy TOPSIS, and Data Envelopment Analysis (DEA) methods were used in a study conducted by Zeydan et al. [41] to solve a problem of supplier selection and evaluation in the automotive sector in Turkey. A new method that transfers the approach of typical of quality function deployment: QFD, to the house of quality (HOQ) method was applied in an automotive industry by Bevilacqua et al. [42] to solve the problem of selecting the best supplier. In order to solve the problem of selecting the best supplier in the automotive production industry, Keskin et al. [43] used the fuzzy-ART: fuzzy adaptive resonance theory (Fuzzy-ART) in his research. For selecting the best supplier in automotive manufacturing company in Malaysia, Jamil et al. [44] used different MCDM methods (AHP, FAHP, TOPSIS, FTOPSIS, and FAHPiFTOPSIS). Dogan and Aydin [45] proposed a combination between Bayesian Network (BN) and Total Cost Ownership (TCO) methods and tested their approach for the supplier selection process. In automotive industry in India, Parthiban et al. [46] utilized first an interpretive structural modeling technique to get the weights for the performance factors that influence the supplier selection process after studied them, and they applied AHP to obtain the rank of suppliers. Using a case of automotive industry in Pakistan, Dweiri et al. [47] proposed a decision support model for supplier selection based on analytic hierarchy process (AHP). For identifying the most important criteria to be used as a baseline for a supplier selection process of automotive sector in India, Sagar and Singh [48] used the questionnaire for data collection and compared with the previous research. Huang and Hu [49] conducted a study with the aim is selection of the best supplier in automotive industry in Taiwan based on use of Fuzzy Analytic Network Process-Goal Programming (FANP-GP) and De Novo Programming (DNP).

3.2 The Entropy Method:

Entropy starts first in thermodynamics with Rudolph Clausius (1865) to describe the irreversibility of the system [61]. The entropy, in a closed physical system, increases over time [62] [63].

The figure below shows the increase of the entropy in a system. When there is the order, the entropy is small, there is no agitation between the particles, and there are no shocks between them as shown in the first picture of the figure below. Whereas when there is a disorder, there is an increase of the entropy, there is a lot of agitation in the particles and there are even shocks between them.

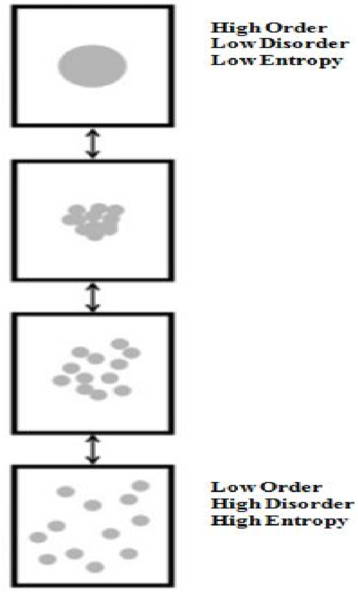

Figure 5: System in order and disorder [58]

On the other hand, It was Shannon who was the first one who developed the theory of entropy of information in 1948 [7].

The theory of Shannon was mainly applied in communication systems such as Radio, Television [58]. A general communication system consists of five parts [7] [59]

- The message is generated by a source S,
- The message is generated by a source S is transmitted to an emitter T, which changes it into a signal that will be transmitted.
- The signal is transmitted from the transmitter to the receiver through the CH channel
- The message is reconstructed from the signal, thanks to receiver R
- The message is received by a destination D

The parts of this communication system are shown in the figure 6 below:

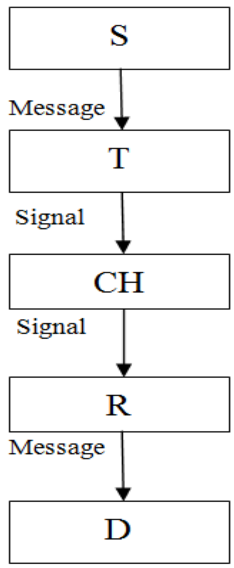

Figure 6: Parts of system communication according to Shannon's theory [7][59]

The Source S is a system with a range of possible states s_1, $s_2 \ldots s_n$ with respective probabilities $p(s_1)$, $p(s_2) \ldots p(s_n)$. The average amount of information produced at the source S is the entropy of the source S:

$$H(S) = -\sum_{i=1}^{n} p(s_i) \log p(s_i) \quad \textbf{(1)}$$

The Destination D is a system with a range of possible states d_1, $d_2 \ldots d_n$ with respective probabilities $p(d_1)$, $p(d_2) \ldots p(d_n)$. The average amount of information produced at the destination D is the entropy of the source D:

$$D(S) = -\sum_{i=1}^{n} p(d_i) \log p(d_i) \quad \textbf{(2)}$$

Without direct inclusion of the decision-maker, the entropy is a method which makes it possible to obtain objective weights of the alternatives [8]. The objective weight is determined by the entropy of Shannon [9]**.** The degree of disorder of a system is measured by Shannon's entropy, which can also be used to define also whether the data grant an effective information or not [11].

In the literature, the entropy of Shannon has been used in several fields. To protect land in China against the expansion of industrialization and urbanization, luo et al. [12] use Entropy method combined with AHP method to assess a more objective weight of indicators that have an effect on intensive land use in districts, counties and other provinces of China. Hamidi et al. [13] use Entropy method combined with AHP method to evaluate the weight of important criteria that affect the selection of the best brands in Iran's beverage industries. Chuansheng et al. [10] use Entropy method combined with AHP method to calculate the weight of criteria impacting the measure of the safety level of smart grids in four regions of China. Li and Zhang [14] use Entropy method combined with AHP method to calculate the criterion that has the great impact on road traffic capacity, especially with the presence of traffic congestion problem caused mainly to the development of cities in China. Entropy was employed, by Zou et al. [9] to determine of weight of evaluating indicators in water quality assessment of a river. Entropy was utilized by Zhengyuan et al. [30] to calculate weight in Fuzzy Comprehensive Model for Evaluation Research of Regional Power Grid Companies' Operation Capacity based on Entropy Weight. To solve the problem of selecting the best supplier, Safari et al. [31] use entropy to calculate the weight of the criteria and uses PROMETHEE to rank the alternatives. To solve the problem of choosing the best supplier, Pani et al. [55] utilized heuristic method (AET) and a combination of AHP, entropy, (TOPSIS). Based on objective weight measurements obtained using Shannon's entropy, Shemshadi et al. [56] then applies a fuzzy VIKOR (Seeing Kriterijumska Optimizacija I Kompromisno Resenje) method to resolve the problem of supplier selection. Entropy method based TOPSIS method was used by Islamoglu et al. (2015) in Tureky, to measure the financial performance of real estate investment trusts.

There are mainly three steps to respect, cited by Chakraborty and Chatterjee [15] when it comes to the application, of any MCDM method to solve a problem of decision-making:

- ✓ Indicate the criteria and alternatives of the problem studied.
- ✓ Determine the measurement of each criterion in relation to the alternatives studied.
- ✓ Rank the alternatives according to their performance measures.

In addition, the weight of the criteria by the entropy method is given by the following steps, [16][24]:

Firstly it is assumed that there is a set of m feasible alternatives, Ai (i = 1,2,…,m) and n evaluation criteria Cj (j = 1,2,…,n) in the problem.

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Step1: The decision matrix which shows the performance of different alternatives A_i (1,2…m)and respect to various criteria C_j (j=1,2…n) is formed.

For:

$$(i = 1,2\cdots,m;\ j = 1,2,\cdots,n)$$

$$X = [X_{ij}]_{m\times n} = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ X_{m1} & X & \cdots & X_{mn} \end{bmatrix} \quad (3)$$

Step2: The decision matrix is normalized. Beneficial (maximization) and non-beneficial (minimization) are normalized by equation (2) and equation (3) respectively:

For $(i = 1,2\cdots,m;\ j = 1,2,\cdots,n)$

$$r_{ij} = \frac{X_{ij} - \min(X_{ij})}{\max(X_{ij}) - \min(X_{ij})} \quad (4)$$

For $(i = 1,2\cdots,m;\ j = 1,2,\cdots,n)$

$$r_{ij} = \frac{\max(X_{ij}) - X_{ij}}{\max(X_{ij}) - \min(X_{ij})} \quad (5)$$

Step3:

Entropy values (e_j) are determined for each criterion:

$$for\ i = 1,2\cdots m;\ j = 1,2\cdots n$$

$$f_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} \quad (6)$$

And

$$e_j = -\frac{\sum_{i=1}^{m} f_{ij}\ln f_{ij}}{\ln m}\ and\ 0\langle e_j\langle 1 \quad (7)$$

If f_{ij} are all the same then the entropy values of each criterion is the maximum (e_j=1), if $f_{ij}\ is\ 0$, then $f_{ij}\ln f_{ij}=0$ [17]

Step4: Entropy weights (W_j) are calculated:

$$W_j = \frac{1-e_j}{n-\sum_{i=1}^{m} e_j}\ where\ \sum_{j=1}^{n} W_j = 1 \quad (8)$$

3.3 Ranking of Values: ROV Method

It is Yakowitz et al. [18] who proposed The range of value (ROV) for the first time in 1993. The ROV method is based on very simple calculation steps, which justifies its use compared to other MCDM methods [19]. The application of the ROV method is very efficient, for decision-makers in the case of quantitative weight problems [20].

Athawale and Chakraborty [21], are conducting a research aimed at selecting the best robot to be used in a given industrial application, while conducting a study of the ranking performance of ten most well-known MCDM methods, among them the ROV method. The ROV method was used by Madić et al. [19] in four cases, to solve cutting fluid selection problems, they find that there was a great correlation between the results obtained using the ROV method and those obtained by previous researchers using others methods of MCDM. To solve a problem of a water management in irrigation district in Mexico, Salazar et al. (1998) compare three multi-criterion decision making techniques: ELECTRE II, Q-analysis and Range of Value (ROV) method [22]. To solve a problem for discrete multi-objective optimization of laser cutting process, Madić et al. [23] use the ROV based Taguchi methodology. Isik and Adalı [24] proposed a combination between the entropy and the the ROV method for resolve a problem of selection of the most appropriate apple for the food company to make apple juice concentrate. In their search Jha et al. [25] proposed ROV method in two examples, to solve a problem of selection of suppliers. It has been applied to problems of watershed management by Yakowitz and Lane [18] , and Yakowitz and Hipel [27]. Hajkowicz and Higgins [20] use the Range of Value (ROV) method, among other methods to solve six water management decision problems.

The application steps of ROV method are presented in the following [23] [20]:

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Step1: The ROV method begins by determining the criteria and alternatives for the problem studied. The decision matrix is presented in Equation (1)

Step2: The decision matrix is normalized by using Eq. (4) and Eq. (5) for beneficial and non-beneficial criteria respectively.

Step 3: The best and worst utility for each alternative are calculated. This is achieved by maximizing and minimizing a utility function. For a linear additive model, the best utility u_i^+ and the worst utility u_i^- of *ith* alternative are obtained using the following equations [20][21] :

Maximize:

$$u_i^+ = \sum_{j=1}^{n} r_{ij} w_j \quad \textbf{(9)}$$

Minimize:

$$u_i^- = \sum_{j=1}^{n} r_{ij} w_j \quad \textbf{(10)}$$

Where w_j are criteria weights which satisfy

$$\sum_{j=1}^{n} w_j = 1 \text{ and } w_j \geq 0$$

Step 5:

If $u_i^- > u_i^+$ then alternative i outperforms alternative i' regardless of the actual quantitative weights. If it is not possible to differentiate the alternatives on this basis then a scoring can be attained from the midpoint, which can be calculated as:

$$u_i = \frac{u_i^+ + u_i^-}{2} \quad \textbf{(11)}$$

On the basis of u_i, that we find the ranking of alternatives, the one with the highest value of u_i is the best alternative, and the worst alternative is the one with the lowest value of u_i

From the above, in the case study, we will apply the combined Entropy-ROV method to obtain the weight of the AKPIs to have a selection of the best Moroccan supplier in automotive sector, in a way, objective and beneficiary.

3.4 Case Study:

3.4.1 Presentation of AKPI's

In his research, Chahid et al [28], developed a model for Performance measurement system by using Performance Measurement Questionnaire (PMQ) to 28 Moroccan automotive suppliers, AKPI and AHP method to obtain a global formula.

The table below shows the Identification of AKPI for each KSF (Key Success Factor) of Moroccan automotive suppliers:

Table 2: Identification of AKPI for each KSF of Moroccan automotive suppliers [28]

KSF	AKPI
Customer Orientation	Rate of Customer Complaint (Cc)
Total Quality	Scrap Rate (Qs)
Efficiency of Production Systems	Machine Availability (Ma)
Internal Climate Favorable	Absenteeism (Ab)
Health and Safety	Number of Occupational Injuries (Oi)
Development of Human Skills	Training Days Person (Tdb)

The table below shows AKPIs calculation methods:

Table 3: AKPIs calculation methods[28]

AKPI	Calculation methods
Cs	The number of customer complaints/ one million hours delivered
Qs	(Non- conformities total / Parts supplied) * 1 Million = PPM Quality PPM Quality/ one million hours delivered
Ma	Ratio between the actual production time and the total time available.
Ab	Number of hours missed/ one million hours delivered
Oi	Number of Occupational Injuries (AT) / one million hours delivered
Tdb	Average number of days of training per employee/one million hours delivered

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3.4.2 Pairwise Comparison Matrix :

The pairwise comparison matrix is in the table 3 below:

Table 4: The pairwise comparison matrix[28]

aij	Cc	Qs	Ma	Ab	Oi	Tdb
Cc	1	1/4	1/7	5	6	1/5
Qs	4	1	1/4	6	7	1/2
Ma	7	4	1	8	9	3
Ab	1/5	1/6	1/8	1	5	1/7
Oi	1/6	1/7	1/9	1/5	1	1/8
Tdb	5	2	1/3	7	8	1

3.4.3 Beneficial AKPI and non-beneficial AKPI

Before starting the weight calculation by the entropy method, one must first, differentiate between the AKPIs that are beneficial and non-beneficial, the table below shows Beneficial AKPI and Non-Beneficial AKPI.

The table shows Beneficial AKPI and non-Beneficial AKPI.

Tableau 5: Beneficial AKPI and Non-Beneficial AKPI

Beneficial AKPI	Non-Beneficial AKPI
Machine Availability (Ma) Training days per person (Tdb)	Rate of Customer Complaint (Cc) Scrap Rate (Qs) Absenteeism (Ab) Number of Occupational injuries (Oi)

3.4.4 The calculation of AKPI weights by Shannon's entropy method

We specify the maximum: Max and the minimum: Min and Max-Min of each column in pairwise matrix presented in the table3, It's before to start the normalization of the matrix.

Tableau 6: Max, Min, Max-Min of each colon in pairwise comparison matrix [28]

a_{ij}	Cc	Qs	Ma	Ab	Oi	Tdb
Cc	1	0,25	0,142	5	6	0,2
Qs	4	1	0,25	6	7	0,5
Ma	7	4	1	8	9	3
Ab	0,2	0,166	0,125	1	5	0,142
Oi	0,166	0,142	0,111	0,2	1	0,125
Tdb	5	2	0,333	7	8	1
Max	7	4	1	8	9	3
Min	0,166	0,142	0,111	0,2	1	0,125
Max-Min	6,834	3,858	0,889	7,8	8	2,875

Using equation (4), we calculate the highest values of: Machine Availability (Ma) Training days per person (Tdb) because they are beneficial AKPI.

We use equation (5) to the smaller values of Rate of Customer Complaint (Cc), Scrap Rate (Qs), Absenteeism (Ab), Number of Occupational injuries (Oi), because they are non-beneficial AKPI.

So the normalization of the pairwise matrix is in the table 6 below:

Table 7: normalization of the pairwise matrix

a_{ij}	Cc	Qs	Ma	Ab	Oi	Tdb
Cc	0,877	0,972	0,034	0,384	0,375	0,026
Qs	0,438	0,777	0,156	0,256	0,25	0,130
Ma	0	0	1	0	0	1
Ab	0,995	0,993	0,015	0,897	0,5	0,005
Oi	1	1	0	1	1	0
Tdb	0,292	0,518	0,249	0,128	0,125	0,304
Sum	3,604	4,261	1,456	2,666	2,25	1,466

Using equation(6), we calculate Fij, the table below shows the calculation of Fij

Table 8: Calcul of Fij

a_{ij}	Cc	Qs	Ma	Ab	Oi	Tdb
Cc	0,243	0,228	0,023	0,144	0,166	0,017
Qs	0,121	0,182	0,107	0,096	0,111	0,088
Ma	0	0	0,686	0	0	0,681
Ab	0,276	0,233	0,010	0,336	0,222	0,004
Oi	0,277	0,234	0	0,375	0,444	0
Tdb	0,081	0,121	0,171	0,048	0,055	0,207

Using equation (7), we calculate eij, the table below shows the calculation of eij:

Table 9: Calculate of eij

AKPI	ej
Cc	0,845
Qs	0,883
Ma	0,523
Ab	0,772
Oi	0,780
Tdb	0,500

Using equation (8), we calculate Wj, the entropy weights of AKPI by entropy method.

The table below shows the weights of AKPI by Entropy method:

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Table10: The weights of AKPI by Entropy method

AKPI	Weight of AKPI by Entropy method
Cc	0,091
Qs	0,068
Ma	0,281
Ab	0,134
Oi	0,129
Tdb	0,295

According to the figure 7, the Training days per person: Tdb is the most important criterion with the highest entropy weight, it is the AKPI that has the most objective weight among the other AKPIs.

Then followed by, respectively by Absenteeism (Ab), Number of Occupational injuries (Oi), Rate of Customer Complaint (Cc) and Scrap Rate (Qs). Qs, is the least important criterion with the smallest entropy weight, and it is the AKPI that has the least objective weight among the other AKPIs.

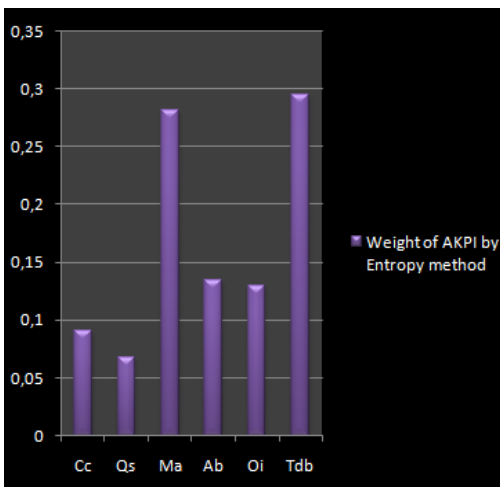

Figure 7: The presentation of weights of AKPI's by Entropy Method

3.4.5 The Ranking of AKPI's weights by ROV Method:

Now we use ROV method for ranking AKPIs, Firstly we use the matrix already normalized in table 6, by the two equations(4) and (5). And we use the weights obtained by the Entropy method in the table 9 to calculate the best and worst utility.

According to the equation (9) The best utility u_i^+ of AKPIs Is in the table 10 below:

Table11: Calculation of the best utility of each AKPI

AKPI	u_i^+
Cc	0,091* [0,034+0,026]
Qs	0,068* [0,156+0,130]
Ma	0,281*[1+1]
Ab	0,134*[0,015+0,005]
Oi	0,129*[0+0]
Tdb	0,295*[0,249+0,304]

According to the equation (9) the worst utility u_i^- Of AKPIs Is in the table 11 below.

Table 12: Calculation of the worst utility of each AKPI

AKPI	u_i^-
Cc	0,091*[0,877+0,972+0,384+0,375]
Qs	0,068*[0,438+0,777+0,256+0,25]
Ma	0,281*[0+0+0+0]
Ab	0,134*[0,995+0,993+0,897+0,5]
Oi	0,129*[1+1+1+1]
Tdb	0,295*[0,292+0,518+0,128+0,125]

Finally we obtain the final calculation of the utility of each AKPI by using equation (11) shown in the table 12 below:

Table13: Utility of AKPI by ROV Method

AKPI	u_i^+	u_i^-	u_i
Cc	0,005	0,237	0,121
Qs	0,019	0,118	0,068
Ma	0,562	0	0,281
Ab	0,002	0,454	0,228
Oi	0	0,519	0,259
Tdb	0,163	0,313	0,238

We rank the weights in percent of AKPIs by the combination of Entropy-Rov method in the table13 below and we will present them in a figure (8) to analyze it.

Table 14: The rank of the weights in percent of AKPIs by the combination of Entropy-ROV Methods

AKPI	Weight of AKPI by the combination of Entropy-ROV Methods	Rank
Cc	12,16%	5
Qs	6,89%	6
Ma	28,12%	1
Ab	22,86%	4
Oi	25,95%	2
Tdb	23,87%	3

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The figure shows that the Machine Availability (Ma) has the first rank with the weight is equal to 0,28: this means that it is the AKPI which is objective and which has the most utility, among the other AKPIs. Then the Number of Occupational injuries (Oi) has the second rank with the weight is equal to 0,25 . Also, Training days per person (Tdb) has the third rank with the weight is equal to 0,23. Rate of Customer Complaint (Cc), Scrap Rate (Qs), Absenteeism (Ab) have the little impact in performance measurement in automotive sector in Morocco.

By applying the combination between ROV and entropy methods we find that: Efficiency of Production Systems and Health and Safety are the prior Key Factor of Success which should be take in consideration in Moroccan automotive sector industry

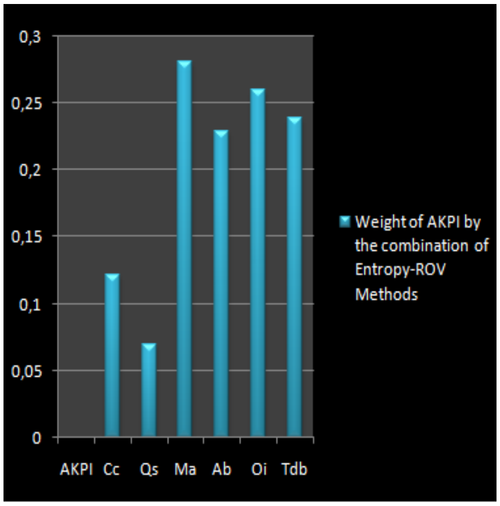

Figure 8: Weights of AKPIs by the combination of Entropy-ROV Methods

3.4.6 Global performance

The global performance (GP) is expressed in the formula below [29]

$$GP = 100 * (P_{AKPI} * \sum_{i=1}^{6} r_i)$$

The formula for overall performance by the combination of Entropy and ROV methods of Moroccan automotive suppliers is calculated as follows:

$$GP = 100*(0{,}12P_{Cc}+0{,}06P_{Qs}+0{,}28P_{Ma}+0{,}22P_{Ab} + 0{,}25P_{Oi}+0{,}23P_{Tdb})$$

3.4.6 Suppliers selection in automotive sector:

The table below shows the pairwise matrix according to AKPIs [67]:

Table 15: pairwise matrix comparison of suppliers [67]

	P_{Cc}	P_{Qs}	P_{Ma}	P_{Ab}	P_{Oi}	P_{Tdb}
Sup1	1	0,9	0,5	0,2	0,8	0,7
Sup2	0,8	0,8	0,7	0,8	0,5	1
Sup3	0,8	0,9	1	0,1	0,5	0,7

For ranking the best supplier among the others, the overall performance of each supplier is calculated using the above formula based on the application of the Entropy-ROV combination.

Table 16: Global Performance of suppliers

Suppliers	GP
Sup1	0,719
Sup2	0,871
Sup3	0,738

We Rank the suppliers in automotive sector by GP based on Entropy-ROV Methods.

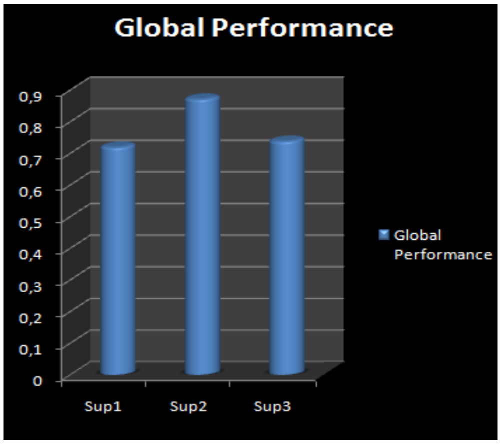

Figure 9: Global Performance of Suppliers

According to the table (15) and figure9, we conclude that Supplier2 has the first rank, followed by supplier 3 and finally supplier 1

4. DISCUSSION

Multi Criteria Decision Making: MCDM has been used to help the decision-maker to solve problems with multiple or conflicting criteria [1]. MCDM enables Decision Maker to rank the alternatives and to choose the best one [2]. The combination of the two methods coordinates the weaknesses of each strategy, the benefits of both, and gives better results [6]. So, we applied the Entropy-ROV combined method.

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The entropy method allowed us to have an objective weight AKPI [9]. The ROV method allowed us to calculate the ranking of AKPI's and to have the best and worst utility of each AKPI according the objective weight calculated by Entropy Method. ROV method does not require complicated calculation, it is simple in use [19].

We have found that the best AKPIs, according to the application of Entropy-ROV methods, are Machine Availability and the Number of Occupational Injuries which correspond respectively to the key success factors Efficiency: Production Systems and Health and Safety. According to the combined method, the two AKPIs are those which have an objective weight, which have more utility, in comparison with others AKPIs. That indicates that these need to be taken into consideration by automotive companies in Morocco. Also, The Entropy-ROV combined method allowed us to calculate the formula for the Global Performance thanks to this formula; we rank the best supplier in the Moroccan automotive sector, we find that the supplier 2 is the best one.

To improve the two key success factors that are health and safety and the system of production, we can create a plan to promote the workplace, train employees and raise awareness by the importance of safety and health at within a Moroccan industrial automotive company. We can also improve the production system while improving the quality and at the same time reducing the losses and minimizing the cost of production.

Comparing our results regarding the weights and ranking of AKPI with those obtained from Chahid et al [28], in the table below:

Table 17: Comparison between the weights of AKPI obtained by the Entropy-ROV method and the AHP method [28]

AKPI	Weight of AKPIs by Entropy-ROV method	Rank	Weight of AKPIs by AHP method	Rank
Cc	12,16%	5	9%	4
Qs	6,89%	6	17%	3
Ma	28,12%	1	43%	1
Ab	22,86%	4	5%	5
Oi	25,95%	2	2%	6
Tdb	23,87%	3	23%	2

By comparing the weights and the classification of the AKPI obtained by the AHP method carried out by Chahid et al. [28], in his research, and our study that we conducted, we notice that the results diverge.

"Ma" Machine Availability is the AKPI that ranks first with the two methods mentioned with a weight of 28.12% in the Entropy-ROV combined method and a weight of 43% with the AHP method. For the second rank, it is the Number of Occupational Injuries "Oi" which is the AKPI with the Entropy-ROV combined method with a weight of 25,95%, while for the AHP method it is "Tdb" Training days per person who gets the second rank with a weight of 23%.

The best AKPIs, according to the application of Entropy-ROV methods, are Machine Availability and the Number of Occupational Injuries, which correspond respectively to the key success factors Efficiency: Production Systems, and Health and Safety while for the AHP method are Machine Availability and Training days per person (Tdb) which corresponds to the key success factors Efficiency: Production Systems and Development of Human Skills.

The difference in results is due to the nature of the method used. The Entropy-ROV combined method is used by the Decision Maker in order to have an objective and utilitarian choice at a time, whereas for the AHP it is for a choice that is subjective: The AHP method provides subjective data that is caused by the variation of judgment from one decision maker to another [68].

Regarding the comparison of Global Performance and the selection of suppliers, the table below shows the difference in overall supplier performance between the Entropy-ROV combined method and the AHP method:

Table 18: The comparison of the Overall Supplier Performance by the Entropy-ROV method and the AHP method.

Supplier	Global Performance by Entropy-ROV method	Global Performance by AHP method
Sup1	0,719	0,65
Sup2	0,871	0,79
Sup3	0,738	0,83

We notice that the supplier 2 gets the first rank by the Entropy-ROV method whereas it is the supplier 3 who gets the first rank by the AHP method. The selection of the best supplier depends on the method used because the results obtained are not the same.

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However, research remains limited as it focuses on choosing the best AKPIs and selecting the best supplier by the Entropy-ROV combined method, but it does not evaluate if there is a capability of the process of delay of purchase in any Moroccan automotive industry.

5. CONCLUSION

The research we conducted through this paper was aimed at two objectives: The first is the application of the Entropy-ROV combined method, for the first time, in the automotive sector in Morocco for the selection of the best AKPI.

After following the steps of the entropy method, we calculated the weight of the AKPI's by this said. The Entropy method is an objective weighting method, which provides an objective weight without considering the decision makers' preferences [9]. This is how the weights obtained from the AKPI are objective. Then ROV was used to classify the AKPIs. ROV allowed us Ranking of AKPI's. Its mode of use is very easy and it is not complicated [19]. The best and worst utility for each AKPI are calculated: [20] [21]. According to Table 13 and figure 8, we found that the first two AKPIs with the objective weight and highest utility value are Machine Availability (Ma) and the Number of Occupational Injuries (Oi) that corresponds respectively to the Efficiency of Production Systems and Health and Safety. The application of the Entropy-ROV combined method allows the decision maker to choose in an objective and utilitarian way, the best two AKPIs in order to improve the Key success factor which corresponds to its respectively.

Second is that we have established the Global Performance formula that will help us rank the best supplier presented in the table and figure: we have found that the best supplier is supplier 2.

In the Discussion section, we deduce that the results are not the same by comparing our results obtained by the Entropy-ROV combined method, with the results obtained by the AHP method of Chahid et al [28]. This gives the choice to the decision-makers, in case they want a subjective evaluation, they will choose the search of Chahid et al.[28] and if they want an objective and utilitarian choice they will choose our search.

Our contribution in this study that we conducted was to bring an application of a combined quantitative and multi-criteria method called Entropy-ROV, for the first time, in the Moroccan industrial automotive sector in order to choose the best AKPI, keys success factors, even to evaluate the suppliers in an objective and utilitarian way.

Our motivation for the next study is to evaluate whether there is a capability of the delay of purchase process, in any Moroccan automotive industry with the application of the six-sigma method.

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